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PRELIMINARY AIR DISPERSION MODELING ANALYSIS OF YELLOWSTONE NATIONAL PARK WEST ENTRANCE WINTERTIME CARBON MONOXIDE EMISSIONS

INTRODUCTION

The Montana Department of Environmental Quality (DEQ) participated as part of the Governor's review team on the Winter Use Plan Draft Environmental Impact Statement for the Yellowstone and Grand Teton National Parks and John D. Rockefeller Jr., Memorial Parkway (DEIS). DEQ was asked to investigate the document for errors, and explore the science of air and water quality as they relate to each of the proposed seven alternatives. Each alternative in the DEIS provided a different scenario and impacts on air and water quality, from Alternative A, No Action, to Alternative F, Close the roads from Mammoth and West Yellowstone, leaving only the roads from Flagg Ranch and Cody open.

The DEIS said that the final Environmental Impact Statement (EIS) might use modeling to evaluate the alternatives. Among other analyses, DEQ conducted preliminary air dispersion modeling of the possible impacts to air quality from the activities described in the DEIS alternatives. This analysis was performed to assist in the decision making process but does not necessarily represent actual events. The model predicted Carbon

Monoxide(CO) concentrations that are thought to have a +/- 30% to 40% confidence level due to limited existing meteorological and CO emissions data. Monitoring data from this past year at the west entrance indicated the average carbon monoxide levels over an 8-hour period may exceed the 9.0 parts per million (ppm) National Ambient Air Quality Standard (NAAQS) before the 1-hour 23.0 ppm Montana standard would be exceeded. However, more data collection is necessary before a final determination can be made. For completeness purposes, this 1-hour standard was examined in the final analysis.

A modeling analysis was performed by the Monitoring and Data Management Bureau, DEQ, to estimate the CO concentrations from vehicle emissions near the roadways at the west entrance of Yellowstone National Park. A U. S. Environmental Protection Agency (EPA) “hot spot” or intersection model, CAL3QHC, was used to predict the CO concentrations from vehicles entering and exiting the Park during the wintertime. This model predicts concentrations of inert air pollutants such as CO from motor vehicle emissions along roadways one hour at a time. A line source dispersion model and a traffic algorithm for estimating vehicular queue lengths at signalized intersections is incorporated into the model. It is considered a screening model that provides a quick, worse case analysis using several broad assumptions including meterological and site characteristics to estimate CO concentrations. Other air pollution models are available, referred to as “refined”, for a more complete, in-depth analysis that requires on-site meteorological data.

The two heaviest wintertime hourly traffic periods were examined during a 24-hour period; these occurred during the morning and evening periods as the vehicles entered and left the Park. Nine total alternatives were examined, A through G; seven of the alternatives were obtained from the DEIS. One of the seven, Alternative E, was slightly modified (E-2) by the local communities and included in this analysis. Howard Haines, DEQ, provided Alternative H; the information for this alternative was suggested in the DEIS, Page 208.

Each option contained variations on the hourly cycle time, fuel usage, type and number of vehicles entering and exiting the entrance. This information and snowmobile CO emissions data were derived from the alternatives in the DEIS, various supporting reports including White et al. (1998, 1999), Kado et al. (1999), and Bishop (1998, 1999), Yellowstone National Park Visitor Services, and confirmed through communications with these researchers and Yellowstone National Park staff. Cycle time is the elapsed time from the passage of one vehicle to the next as they stop and go through the entrance station, much as would occur at an intersection with a traffic signal. The other vehicular CO emission factors were obtained from the USEPA Compilation of Air Pollutant Emission Factors – Volume II: Mobile Sources, AP-42, and Emission Facts: Idling Vehicle Emissions. These emission factors were selected for high altitude and wintertime temperatures.

The air dispersion model used for this study has limits to the maximum input traveling and idling CO emission rates, 1,000 grams/mile and 1,000 grams/hour, respectively. When an alternative scenario required an emission rate greater than one of these maximums, for example Alternative A, the limit was entered into the model.

FEDERAL AND MONTANA HOURLY CO STANDARDS

The 1-hour National Ambient Air Quality Standard (NAAQS) for CO is 35.0 ppm not to be exceeded more than once a calendar year. The hourly Montana Ambient Air Quality Standard (MAAQS) is 23.0 ppm for CO not to be exceeded more than once a calendar year, 34 percent less than the Federal standard. The Montana standard was based on an epidemiological evaluation conducted by Montana during 1979-1980. Other states with a different hourly CO standard than the federal one are California and New Mexico, 20.0 and 13.1 ppm, respectively. The 8-hour average CO NAAQS and MAAQS standards are 9.0 ppm not to be exceeded more than once a calendar year.

MODELING VERSUS MONITORING

The model predicts the maximum 1-hour CO concentrations at each location (receptor) and wind direction that has been manually entered by the user; these locations represent areas where the public has access. According to the model requirements, these receptors cannot be located within 10 feet (3.0 meters) of the traveled roadways or within tollbooths (kiosks), intersections, or crosswalks. Another receptor is included to represent the local CO monitoring station if one exists. Monitoring stations are placed near the sources of pollutants according to stringent USEPA siting criteria. For a microscale CO site, such as the one located at the west entrance of the Park, the inlet to a CO measurement instrument must be between 2 and 10 meters (7 and 33 feet) from the roadway edge and sufficiently distant from obstacles that obstruct air flow such as buildings and vegetation to assure representative data.

The locations of the highest 1-hour CO concentrations predicted by the model will not necessarily correspond to the location of the CO monitoring station receptor. The type, number, and activity of the vehicles (entering or exiting the park entrance), and wind direction will affect where the model calculates the maximum CO concentration.

Compliance with the hourly National and Montana CO standards is determined by the second highest hourly concentration, but the model only provides the first. Therefore, the model results can only be applied as a rough estimate whether compliance with the standards will occur. Also, air pollution modeling focuses on the public's exposure to air pollution so the highest CO concentration predicted, regardless of the location, is used for comparison to the standards. In reality, the data collected at the monitoring inlet will determine the area's compliance status.

After the preliminary analysis, selected alternatives were evaluated in reference to both 1-hour CO NAAQS and MAAQS. CAL3QHC does not provide any information pertaining to the 8-hour average CO standards. A "persistence factor" can be applied to the 1-hour concentrations to estimate the 8-hour CO concentrations. A persistence factor indicates the longevity of the carbon monoxide in the atmosphere within an area and is usually estimated using on-site CO data. However, due to limited wintertime CO data collected at the west entrance, a typical persistence factor was used in this analysis, 0.75.

BACKGROUND CO CONCENTRATION

CAL3QHC is an intersection or "hot spot' model developed to examine the impacts of vehicles entering and leaving a small study area on an hourly basis. This model evaluates only the direct effects of CO emitted by the vehicles included in the model input file. The results do not include CO impacts from all other sources that are close enough to affect the air quality at the receptor locations. Indirect impacts from these sources are added to the model results as "background" CO. These sources include CO from residential wood burning and vehicle emissions in West Yellowstone. The CAL3QHC model also does not have any way to account for residual CO still remaining in the atmosphere from emissions during a previous time period. CAL3QHC starts each analysis with the assumption that the current CO level is zero. This assumption is often appropriate, but under the stagnant conditions resulting from strong and persistent atmospheric temperature inversions and very low wind speeds often present in Montana, residual CO can have a dramatic effect on ambient CO concentrations. Carbon monoxide is not a reactive species and unless some dispersion is available, CO ambient levels can remain high for several hours after the emissions have been reduced to very low levels. These residual CO effects must also be factored into the background value used to determine the final model results.

Generally, a background value is obtained from direct measurement at the site of interest. In October 1998, DEQ installed a microscale carbon monoxide monitoring station (30-031-0013) on the northeast side of the Yellowstone National Park west entrance. Due to machine malfunction, minimal wintertime data was collected. The highest hourly CO concentration, 18.1 ppm (parts per million) was measured on February 13, 1999 for the 5:00 to 6:00 P.M. period. The CO concentrations decreased to 3.1 ppm for the 11:00 P.M. to 12:00 A.M. period. Reviewing the data and using the Monitoring and Data Management Bureau staff professional judgement, a 5.0 ppm background CO concentration was selected to represent the worse case residual impact of CO during stagnation periods.

RESULTS

The following is a summary table of the hourly traveling and idling vehicular CO emissions, and the maximum 1-hour CO concentrations predicted by the air dispersion model for each of the nine alternatives including the 5.0 ppm background CO concentration. Also listed are the percentages of the alternative emissions and concentrations relative to Alternative A (Baseline).

Summary table of the hourly traveling and idling vehicular CO emissions, and the maximum 1-hour CO concentrations predicted by the air dispersion model for each of the nine alternatives including the background CO concentration; concentrations below the 35.0 ppm 1-hour NAAQS are italicized.

Option	**Description**	**Hourly Traveling Vehicle CO Emissions (kilograms/mile)**		**Percentage of Alternative A (%)**		**Hourly Idling Vehicle CO Emissions (kilograms/ hour)**	**Percentage of Alternative A (%)**	**First Highest 1-Hour CO Concentration (ppm)** [a]		**Percentage of Alternative A (%)**	
		A.M.	**P.M.**	**A.M.**	**P.M.**	**A.M. Only**		**A.M.**	**P.M.**	**A.M.**	**P.M.**
A	Baseline: Snowmobiles and Snowcoaches	**790.2 (1,740.5 lb.)** [b]	**351.1 (772.4 lb.)**	•	•	**123.8 (272.4 lb.)**	•	**50.8 (with 24 sec. stop time)**	***31.7***	•	•
B	Only Wheeled Public Shuttle Service, Road Plowed	6.6 (14.5 lb.)	4.8 (10.6 lb.)	0.8	1.4	23.6 (51.9 lb.)	19.0	*12.3*	*5.3*	22.5	16.7
C	Alternative B with Ethanol for All Gasoline Fueled Vehicles, Roads Plowed	5.0 (11.0 lb.)	4.0 (8.8 lb.)	0.6	1.1	19.7 (43.3 lb.)	15.9	*11.0*	*5.3*	20.0	16.7
D	Approx. 40% of Alternative A	497.4 (1,094.3 lb.)	142.1 (284.2 lb.)	63.0	40.5	52.7 (115.9 lb.)	42.6	*27.3*	*15.7*	49.9	49.5
E-1 Modified	Alternative A with Oxygenated Fuel and Low Emissions Lube Oil	708.2 (1,560.0 lb.)	281.1 (618.4 lb.)	89.6	80.1	88.4 (194.5 lb.)	71.4	41.9	*26.4*	76.6	83.3
E-2 Modified	Similar to Alternative E-1 with No Stopping, All Vehicles @15 miles per hour	423.1 (931.9 lb.)	•	53.5	•	•	•	*28.0*	•	55.1	•
F	Roads Closed to All Traffic	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*	*0.0*	0.0	0.0
G	Access by Snowcoaches Only	13.2 (29.0 lb.)	13.2 (29.0 lb.)	1.7	1.5	0.0	0.0	*6.1*	*6.0*	11.2	18.9
H	Alternative A with 80% Electric Snowmobiles	178.2 (392.0 lb.)	72.9 (160.4 lb.)	22.6	20.7	29.0 (63.8 lb.)	23.4	*14.4*	*10.4*	26.3	32.8

[a] ppm = parts per million.
[b] lb. = pounds.

The following table lists the percentage source contribution and source concentration to the maximum 1-hour CO concentrations of the nine alternatives without the 5.0 ppm background CO concentration; concentrations below the 1-hour NAAQS are italicized.

Alternative	Percentage Source Contribution (CO Concentration – ppm)								
	Max 1-Hour CO Conc. (ppm) [a]	Snowmobile	Snowcoach	18 Wheeler Diesel Truck	Snowplow	Light Gas Truck	Gas Personal Car	Touring Diesel Bus	Gas Shuttle Van
A **A.M.**	49.7	99.3 (45.5 ppm)	0.7 (0.3 ppm)	0.0 (0.0 ppm)	•	•	•	•	•
A **P.M.**	*26.7*	99.6 (26.6 ppm)	0.4 (0.1 ppm)	0.0 (0.0 ppm)	•	•	•	•	•
B **A.M.**	*7.3*	•	•	•	0.0 (0.0 ppm)	26.0 (1.9 ppm)	15.1 (1.1 ppm)	9.6 (0.7 ppm)	49.3 (3.6 ppm)
B **P.M.**	*0.3*	•	•	•	0.0 (0.0 ppm)	33.3 (0.1 ppm)	33.3 (0.1 ppm)	33.3 (0.1 ppm)	0.0 (0.0 ppm)
C **A.M.**	*6.0*	•	•	•	0.0 (0.0 ppm)	25.0 (1.5 ppm)	15.0 (0.9 ppm)	11.7 (0.7 ppm)	48.3 (2.9 ppm)
C **P.M.**	*0.3*	•	•	•	0.0 (0.0 ppm)	33.3 (0.1 ppm)	33.3 (0.1 ppm)	33.3 (0.1 ppm)	0.0 (0.0 ppm)
D **A.M.**	*22.3*	94.2 (21.0 ppm)	5.8 (1.3 ppm)	0.0 (0.0 ppm)	•	•	•	•	•
D **P.M.**	*10.7*	100.0 (10.7 ppm)	0.0 (0.0 ppm)	0.0 (0.0 ppm)	•	•	•	•	•
E-1 Modified **A.M.**	36.9	98.1 (36.2 ppm)	1.9 (0.7 ppm)	0.0 (0.0 ppm)	•	•	•	•	•
E-1 Modified **P.M.**	*21.4*	99.5 (21.3 ppm)	0.5 (0.1 ppm)	0.0 (0.0 ppm)	•	•	•	•	•
E-2 Modified **A.M.**	*23.0*	99.6 (22.9 ppm)	0.4 (0.1 ppm)	0.0 (0.0 ppm)	•	•	•	•	•
G **A.M.**	*1.1*	•	100.0 (1.1 ppm)	•	•	•	•	•	•
G **P.M.**	*1.0*	•	100.0 (1.0 ppm)	•	•	•	•	•	•
H **A.M.**	*9.4*	95.7 (9.0 ppm)	4.3 (0.4 ppm)	0.0 (0.0 ppm)	•	•	•	•	•
H **P.M.**	*5.4*	98.2 (5.3 ppm)	1.8 (0.1 ppm)	0.0 (0.0 ppm)	•	•	•	•	•

Model results for Alternatives A and E-1, an Alternative A derivative, exceeded the 1-hour CO NAAQS for the morning period whereas none of the alternatives exceeded the 1-hour CO NAAQS for the evening indicating that the morning period was the limiting time period. The model results also revealed that the snowmobiles traveling in the express lane had the greatest contributions to the CO concentrations, over 98 percent, due to the high CO emission factors of the 5 miles per hour (MPH) traveling speed. Increasing the traveling speed to 15 MPH would have decreased the emissions by about 42 and 54 percent, respectively, and an exceedance of the 35 ppm NAAQS would not have occurred. The use of oxygenated fuel and low emission lube oil did not reduce the CO emissions sufficiently to prevent an exceedance of the 1-hour NAAQS. The low traveling speed of the snowcoaches, 5 MPH, had a large CO emission factor, but the snowcoaches had little impact on the estimated CO concentrations due to their substantially lower numbers.

Using the 0.75 persistence factor, only the Alternative A morning period vehicle emissions would have exceeded the 8-hour CO NAAQS. However, this is a mathematical operation that does not necessarily reflect reality. It is more likely for an exceedance of the 1-hour NAAQS to occur during the morning period and an exceedance of the 8-hour average NAAQS to occur in the late afternoon when stagnation conditions steadily intensify as demonstrated by the CO concentrations used to estimate the background CO concentration. On February 13, 1999, the hourly CO concentrations steadily increased to 8.1 ppm during 4:00 to 5:00 P.M. period, peaked to 18.1 ppm during the 5:00 to 6:00 P.M. period, then slowly decreased to 3.1 ppm for the 11:00 P.M. to 12:00 A.M. period. This pattern shows the strength of stable wintertime atmospheric conditions on the poor dispersion of CO and the impact of residual CO discussed previously.

The predicted morning hourly CO concentration calculated for Alternative A was almost 40 percent greater than the 31.0 ppm measured by grab bag sampling (DEIS). The predicted maximum 1-hour results represent a “worst case” scenario where the maximum emissions coincide with the worst dispersion conditions. Since the maximum emission scenarios only occur for a few hours each year the probability of these events occurring simultaneously is small. These events are a very high number of hourly snowmobiles (900+) with current emissions lined up at the park entrance traveling at low speeds, extremely stagnant wintertime atmospheric conditions with very low wind speeds essentially in line with the traffic lane, and the residual effect of high snowmobile activity that occurred during the previous hour. Given the ambient levels that have been reported to date and these modeling results, it is apparent that the potential for violations of the ambient CO standards is large. The greatest uncertainty in this analysis is probably the CO emission rate determination. Snowmobile emissions are not as well studied as automobile emissions and it is the Monitoring and Data Management Bureau staff‘s professional judgement that the actual emissions could easily be ∀ 30 – 40 percent more or less than those used in the modeling. Since the predicted result for the Alternative A morning scenario is nearly 40% greater than the CO standard, it is the opinion of the Monitoring and Data Management Bureau (MDMB) staff that if the current emission pattern persists and the CO monitor is left in place, a monitored violation will eventually occur

Although there were twice as many diesel buses in Alternatives B and C as gasoline vehicles, diesel engines are more efficient in cold weather than gasoline engines as reflected in their CO emission factors so their emissions were less. The use of ethanol in gasoline vehicles reduced the CO emissions by about 20%, but the effect on the CO concentrations were insignificant due to the low vehicle volumes.

A similar modeling analysis using CAL3QHC was performed by MDMB on an intersection in Kalispell (Malfunction Junction: U.S. Highways 2 and 93), Montana. For comparison purposes, the highest 1-hour CO concentration estimated for this intersection was 20.4 ppm in 1998 including a 2.0 ppm background value. The modeled average wintertime hourly traffic was about 3,140 total road vehicles. However, passenger vehicles have substantially lower traveling CO emission rates than snowmobiles and the road traffic at the intersection was traveling four different directions. At 25 mph, road vehicles emit around 45 grams/mile CO compared to 348 grams/mile for current snowmobiles, about 87 percent less. As an example, assume 600 snowmobiles traveled one mile at 25 mph. Over 4,640 road vehicles would need to travel the same speed and distance to emit the same amount of CO. Idling CO emission rates are over 50 percent greater for road vehicles (771 grams/hour) than for snowmobiles (395 grams/hour).

Additional modeling was conducted on Alternatives A (baseline), E-2 (Alternative A with 15 MPH vehicle traveling speed), and H (in which 80 percent of the snowmobiles would be electric). The maximum number of snowmobiles that could pass the entrance station per hour under each alternative emission activity before a 1-hour CO NAAQS and MAAQS exceedance would occur was determined. These numbers of snowmobiles for each alternative are listed in the following table.

<u>Alternative</u>	**Maximum Number of Snowmobiles Before 1-Hour CO NAAQS Exceedance <u>(35.0 ppm)</u>**	**Maximum Number of Snowmobiles Before 1-Hour CO MAAQS Exceedance <u>(23.0 ppm)</u>**
A	558	345
E-2	1,170	700
H	2,790	1,725

Regardless of the alternative, there was about a 60 percent difference in the number of snowmobiles between the two standards. This is about 6 percent less than the mathematical difference between the two standards. There was also about a 40 percent difference between the two alternatives, regardless of the standard showing the impact of 80 percent electric snowmobiles on the reduction of CO emissions.

CONSIDERATIONS AND POTENTIAL CONTROL STRATEGIES

Re-entrained road dust due to the wintertime application of sanding traction materials has been a prevalent springtime PM-10 problem in Montana causing exceedances of the PM-10 NAAQS; (PM-10 is particulate 10 microns or less in aerodynamic diameter). Limited application of sand for winter traction does occur in some areas in the Park and near Gardiner, but DEQ has no information available to determine if there is a re-entrained road dust problem at spring thaw. To prevent this problem, the characteristics of the sanding material (i.e. size, durability, etc.), the amount of sanding material applied, and the frequent removal (i.e., sweeping) of the material should be included in the analysis of Alternatives B and C. In addition, the effects of re-entrained road dust on the new PM-2.5 NAAQS is currently unknown; (PM-2.5 is particulate 2.5 microns or less in aerodynamic diameter). Although the PM-2.5 fraction in re-entrained road dust is probably small, it must be considered.

The release of CO from residential wood burning in West Yellowstone may have some impact on the CO measurements at the park west entrance. This portion of the measured CO concentration was considered part of the background CO concentration. Special ambient air monitoring must be conducted in Yellowstone Park before the impact from residential wood burning can be quantified. From studies conducted in other Montana communities by MADM, the contribution of CO from residential wood stoves during a wintertime day can vary from 20 to over 40 percent. Some past successful control strategies have been enforceable residential curtailment wood burning programs during high pollutant days and tax incentives or regulations for stove replacements with certified stoves of low CO emissions.

Requiring park entrance tickets to be pre-purchased and allowing relatively high vehicle speeds (25 mph or more) would substantially reduce CO emissions and may prevent violations of the state and federal standards.

Another control option discussed in the DEIS was the use of cleaner, alternate fuel technologies. Several new technologies are in various stages of development such as electric snowmobiles, 2-stage catalytic converters, 2-stroke direct fuel injection engines, 4-stroke engines for cold weather applications, and a biodegradable super-low emissions lubricant. The analysis of Alternative H shows what might be possible as these technologies develop

SUMMARY

The application of USEPA CAL3QHC provided a preliminary air dispersion modeling analysis of the wintertime carbon monoxide emissions at Yellowstone National Park west entrance from the vehicle activities of nine scenarios primarily outlined in the Winter Use Plan Draft Environmental Impact Statement for the Yellowstone and Grand Teton National Parks and John D. Rockefeller Jr., Memorial Parkway (DEIS). However, it was not a study that reflected actual events due to limited existing meteorological and snowmobile CO emissions data that contributed to a ∀ 30 – 40 percent confidence level, but the results can be used for comparative purposes. This “hot spot” or intersection model estimates the maximum 1-hour CO concentration at each inputted location and wind direction using broad on-site and meteorological assumptions. From limited on-site CO data, a 5.0 ppm background CO concentration was estimated. The highest trafficked morning and evening periods for the majority of alternatives were examined. From this analysis, the following conclusions were developed:

- Morning period Alternatives A and E-1, an Alternative A derivation, exceeded the 1-hour CO NAAQS. Snowmobiles traveling at very low speeds, 5 MPH, contributed over 98 percent to the CO concentrations due to the associated very large CO emission factors.

- Using oxygenated fuel with the low emission lube oil did not sufficiently reduce CO emissions and prevent an exceedance of the NAAQS at very low travel speeds, 5 MPH.

- Snowcoaches contributed less than one percent to the CO concentrations due to the low hourly volume even though their CO emission factors were high.

- Although there were twice as many diesel buses in Alternatives B and C, diesel engines are more efficient in cold weather than gasoline engines as reflected in their lower CO emission factors so their emissions were less.

- The use of ethanol in gasoline vehicles significantly reduced the CO emissions by 20%, but the concentrations were so low due to the vehicle volumes that the impact was low.

- NAAQS would not be exceeded if snowmobile speeds though the entrance station were increased to 15 mph.
- Up to 558 snowmobiles per hour could be admitted into the Park without violating the one hour CO NAAQS. MAAQS would allow up to 345 machines to enter per hour.
- There was about a 60 percent difference in the number of snowmobiles between the 1-hour NAAQS and MAAQS using the same alternative emissions scenario. This is about 6 percent less than the mathematical difference between the two standards.

- No definitive information on the 8-hour NAAQS could be obtained from the modeling analysis.

- Further air dispersion modeling using representative on-site meteorological data and snowmobile CO emission factors is necessary to adequately quantify the CO emissions from wintertime vehicles at the west entrance of Yellowstone National Park.

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WEST YELLOWSTONE NATIONAL PARK ENTRANCE ASSUMPTIONS

- 5 total lanes: at 12 feet wide each; Lane 5 is farthest from CO monitoring station.
- Morning Period: 4 lanes used (Lanes 2-5).
- Evening Period: 3 lanes used (Lanes 1-3).
- CO monitoring station to edge of road 3.5 meters (11.5 feet) and 25.6 meters (84 feet) west of a hypothetical centerline that runs through the center of the ticket booths north to south.
- The canopy over the ticket booths has no effect on the CO atmospheric dispersion.

VEHICLE ASSUMPTIONS

- All vehicles move at a constant rate when entering or exiting the park.
- No vehicle stopped when exiting the park.
- Cycle time for vehicles that simulate a roadway intersection, except for the snowmobiles: 68 total seconds, 60 seconds red and 8 seconds green.

- Cycle time for snowmobiles that simulate a roadway intersection: 30 total seconds, 24 seconds stop, and 6 seconds green time.

MODEL ASSUMPTIONS

- Assumed vehicular stoppage at the ticket booth simulates a signalized intersection.
- Worse case wind speed (1.0 meter per second).
- Averaging Time: 60 minutes.
- Wind Direction: every 5 degrees, 0 – 360 degrees wind is coming from

  (0 = positive Y-axis).
- Surface Roughness Coefficient: 2833.0 cm (fir forest).
- Flat Topography.
- Surface type: at grade.
- Settling Velocity: 0.0 cm/s.
- Number of Receptors: 17; along south vehicle entrance queue (morning period) and along the north exit queue. Receptor height = 1.8 m (height of normal man). Receptors are location where the CO concentration is calculated. These locations must be at least 3.0 meters away from the edge of the road. They cannot be placed inside the park entrance ticket booths.
- Source Height = 0.0 m (default).
- Stability Class: D (stable atmospheric condition).
- Atmospheric Mixing Height: 1,000 meters for morning and evening periods (default).
- Saturation Flow Rate was to the default (1600).
- Signal Type was set to the default (pretimed).
- Arrival type was to the default (random arrivals).

Low wind speeds and stable atmospheric conditions prohibit good dispersion of emitted CO away from its sources; low mixing heights keeps the carbon monoxide near the ground level.

ALTERNATIVES

The following is a brief description of each alternative:

Alternative A: No Action. No oxyfuels used.

Worse Case Morning Period: 8:00 – 9:00 A.M.

600 Gasoline Snowmobiles [1] in Express Lane 2 at 10 mph; traveling emission factor = 800.0
grams per mile (gm/mi.)

300 Gasoline Snowmobiles in Lanes 3 and 4 at 5 mph; traveling emission factor =1,000.0 gm/mi.
Idling emission factor = 395.00 grams per hour (gm/hr).

10 Gasoline Snowcoaches [2] in Lane 5 at 5 mph; traveling emission factor = 1,000.0 gm/mi.
Idling emission factor = 487.0 gm/hr.

4 18-Wheelers Diesel Trucks [3] in Lane 5 at 5 mph, traveling emission factor = 47.5 gm/mi.
Idling emission factor = 94.6 gm/hr.

Diesel trucks followed the snowcoaches in Lane 5.

Worse Case Evening Period: 5:00 – 6:00 P.M.

1000 Gasoline Snowmobiles in Lanes 1 and 2 at 25 mph; traveling emission factor = 348.0
gm/mi.

12 Gasoline Snowcoaches in Lane 3 at 25 mph; traveling emission factor = 243.1 gm/mi.

4 18-Wheelers Diesel Trucks in Lane 3 at 10 mph, traveling emission factor = 32.8 gm/mi.

Diesel trucks followed snowcoaches in Lane 3.

Alternative B: Only Wheeled, Public Shuttle Diesel Busses Used (DEIS, Vol. I., Page 27).

Worse Case Morning Period 8:00 – 9:00 A.M.:

20 Light Gasoline Trucks [4] in Lane 2 at 10 mph; traveling emission rate = 109.9 gm/mi.

Idling emission rate = 487.0 gm/hr.

3 Snowplow [5] in Lane 2 at 10 mph; traveling emission factor = 32.8 gm/mi.

10 Gasoline Personal Cars [6] in Lane 3 at 10 mph; traveling emission factor = 92.7 gm/mile.

Idling emission factor = 371 gm/hr.

42 (40 passenger) Touring Diesel Buses [7] in Lane 4 at 10 mph; traveling emission factor = 32.8 gm/mi.

Idling emission factor = 94.6 gm/hr.

12 Gasoline Shuttle Vans [8] (15 passenger) in Lane 5 at 10 mph; traveling emission factor = 109.9 gm/mi.

Idling emission factor = 487.0 gm/hr.

Trucks follow snowplow in Lane 2.

Worse Case Evening Period: 5:00 – 6:00 P.M.

40 Gasoline Personal Cars in Lane 1 at 25 mph; traveling emission factor [5] = 34.7 gm/mile.

3 Snowplow in Lane 1 at 10 mph, traveling emission rate = 32.8 gm/hr.

20 Light Gasoline Trucks in Lane 2 at 10 mph; traveling emission rate = 74.5 gm/mi.

12 Gasoline Shuttle Vans in Lane 2 at 25 mph; traveling emission factor = 44.51 gm/mi.
42 Diesel Buses in Lane 3 at 10 mph; traveling emission factor = 32.8 gm/mi.
Vans followed Trucks in Lane 2.

Alternative C: Same as Alternative B, but use ethanol blend for all gas vehicles (DEIS, Vol. I, Page 30). All gasoline CO emission factors reduced by 20 percent.

Alternative D: same as Alternative A using given CO emission factors (DEIS, Vol. I, Page 10, Bishop and Stedman, 1999).

Alternative E-1: same as Alternative A with given CO emission factors (Revised Alternative E (9/27/99 – Wyoming), White and Carroll, 1998).

Alternative E-2: same as Alternative E-1 with All Vehicles [1, 2] traveling at 15 miles per hour (MPH) without stopping at the park entrance (Revised Alternative E (9/27/99 Draft – Wyoming).

Alternative F: no modeling due to no vehicles = 0.0 emissions.

Alternative G: Snowcoaches [2] used only.
Worse Case Morning Period 8:00 – 9:00 A.M.:

120 Gasoline Snowcoaches in Lanes 5 and 4 at 10 mph; traveling emission factor = 109.9 gm/mi. (DEIS, Vol. I, Page 36).

Worse Case Evening Period: 5:00 – 6:00 P.M.

120 Gasoline Snowcoaches in Lanes 1 and 2 at 10 mph; traveling emission factor = 109.9 gm/mi.

Alternative H: same as Alternative A, but with 80% Electric Snowmobiles.

This percentage was applied proportionally to the 600 entering snowmobiles without delay and 300 snowmobiles that stopped at the entrance (DEIS, Page 208 and Speech by Mike Finley, Superintendent, Yellowstone National Park, August 17, 1997 on CNN).

CO EMISSION FACTORS AND CALCULATIONS

[1] Following snowmobile data provided by Howard Haines, DEQ.

Alternative A: Baseline Gasoline CO Emissions:

Vehicle Miles/Hour	Grams/Mile	Grams/Hour
0	NA [a]	395
5	1741	NA
15	580	NA
25	348	NA
35	249	NA

[a] NA = Not Applicable.

Ref: DEIS, p. 27, White et al., 1998.

Calculation for 10.0 mph: Graphed the 4 points on graphing paper. Estimated a curvilinear line through all 4 points since it is well known that this relationship exists between CO emissions and with vehicle speed (mph). An 800 gm/mi. emission factor was approximated and used.

Alternative D: NPS recommended level, about 40% of Baseline:

Vehicle Miles/Hour	Grams/Mile	Grams/Hour
0	NA [a]	158
5	696	NA
15	232	NA
25	139	NA
35	99	NA

[a] NA = Not Applicable.

Ref: DEIS, Vol. I. p. 27, 33.

Calculation for 10.0 mph: Graphed the 4 points on graphing paper. Estimated a curvilinear line through all 4 points since it is well known that this relationship exists between CO emissions and with vehicle speed (mph). A 360 gm/mi. emission factor was approximated and used.

Alternative Amended E: Oxygenated Fuel and Low Emission Lube Oil:

Vehicle Miles/Hour	Grams/Mile	Grams/Hour
0	NA [a]	277
5	1,388	NA
15	463	NA
25	278	NA
35	198	NA

[a] NA = Not Applicable.

Ref: White et al., 1998.

Calculation for 10.0 mph: Graphed the 4 points on graphing paper. Estimated a curvilinear line through all 4 points since it is well known that this relationship exists between CO emissions and with vehicle speed (mph). A 680 gm/mi. was approximated and used.

Snowmobiles: Needed 10 mph, given 5 and 15 mph, calculated average = 1,160.5. CAL3QHC CO emission limit = 1,000.00 therefore used 1,000.00 gm/mi.

[2] Bombardier High Altitude Light Duty Gasoline Truck for CO at 5.0 mph = 1,526.06 gm/mi., 25° F, 100% cold starts, calendar year = 1980 since the Bombardier that have no emission controls similar to pre-1970 V-8 and the tables do not precede 1980. Used maximum allowed CAL3QHC CO emission factor = 1,000.0 gm/mi. (Compilation of Air Pollutant Emission Factor – Volume II: Mobile Sources, Table J-27). Idling for CO = 487.0 gm/hr winter conditions: 30° F, 13.0 psi RVP gasoline (Emission Facts: Idling Vehicle Emissions). Appendix J High Altitude not available for 25.0 mph, but have Tables J-29 and J-30 High Altitude for 19.6 and 35.0 mph, respectively. Averaged the data for the two types of Snowcoaches and prorated based on number of each type. 10 Bombardier; High Altitude, Light Duty Gasoline Truck for CO at 25 mph = 293.46 gm/mi. (19.6 mph) + 192.72 gm/mi. (35.0 mph) = 486.18/2 = 243.1 gm/mi., 25° F, 50% cold starts 50% stabilized 50% hot starts, calendar year = 1980. Gasoline Snowcoaches in Lanes 1 and 2 at 10 mph; traveling emission factor = 109.9 gm/mi. (DEIS o. 38). No table available for 15 miles per hour (MPH). Graphed 5.0, 10.0, 19.5 and 35.0 MPH, 25° F, 100% cold starts, calendar year = 1980, and approximated 15 MPH = 630 gm/mi. (Compilation of Air Pollutant Emission Factor – Volume II: Mobile Sources, Tables J-27 - 30).

[3] 18-Wheelers Diesel Trucks High Altitude Heavy Duty Diesel Truck for CO at 5.0 mph = 47.51 gm/mi., 0 - 100° F, calendar year = 2000 (Compilation of Air Pollutant Emission Factor – Volume II: Mobile Sources, Table J-27). Idling: for CO = 94.60 gm/hr winter conditions: 30° F, 13.0 psi RVP gasoline, and using the Altitude High Adjustment Factor (3.182) = 301.02 gm/hr (Emission Facts: Idling Vehicle Emissions). High Altitude Heavy Duty Diesel Truck for CO at 10.0 mph = 32.76 gm/mi., calendar year = 2000 (Compilation of Air Pollutant Emission Factor – Volume II: Mobile Sources, Table J-28). No table available for 15 miles per hour (MPH).

Graphed 5.0, 10.0, 19.5 and 35.0 MPH, 0 - 100° F, calendar year = 2000, and approximated 15 MPH = 24 gm/mi. (Compilation of Air Pollutant Emission Factor – Volume II: Mobile Sources, Tables J-27 - 30).

[4] Light Duty Gasoline Truck (includes passenger vans) High Altitude for CO at 10.0 mph = 109.93 gm/mi., 25° F, calendar year = 2000, 100% cold stars (Compilation of Air Pollutant Emission Factor – Volume II: Mobile Sources, Table J-28). Idling: for CO = 487.00 gm/hr winter conditions: 30° F, 13.0 psi RVP gasoline (Emission Facts: Idling Vehicle Emissions). Light Duty Gasoline Trucks (includes passenger vans) for CO at 10.0 mph = 74.51 gm/mi., 25° F, calendar year = 2000, 50% cold starts 50% stabilized 50% hot starts (Compilation of Air Pollutant Emission Factor – Volume II: Mobile Sources, Table J-28).

[5] Snowplow, High Altitude Heavy Duty Diesel Truck for CO at 10 mph = 32.76 gm/mi., calendar year = 2000. (Compilation of Air Pollutant Emission Factor – Volume II: Mobile Sources, Table J-28). Idling for CO = 94.6 gm/hr winter conditions: 30° F, 13.0 psi RVP gasoline (Emission Facts: Idling Vehicle Emissions.

[6] Gasoline Personal Passenger Vehicle, High Altitude, Light Duty Gasoline Vehicle for CO at 10 mph = 92.7 gm/mi., 25° F, 100% cold start, calendar year = 2000, (Compilation of Air Pollutant Emission Factor – Volume II: Mobile Sources, Table J-28). Idling for CO = 371.0 gm/hr winter conditions: 30° F, 13.0 psi RVP gasoline (Emission Facts: Idling Vehicle Emissions). Appendix J High Altitude not available for 25.0 mph, but have Tables J-29 and J-30 High Altitude for 19.6 and 35.0 mph, respectively. Averaged the data: 41.61 gm/mi. + 27.83 gm/mi. = 69.44/2 = 34.72 gm/mi.,

25° F, calendar year = 2000, 50% cold starts 50% stabilized 50% hot starts.

[7] Diesel Buses, High Altitude Heavy Duty Diesel Vehicles for CO at 10 mph = 32.8 gm/mi., 25° F, calendar year = 2000 (<u>Compilation of Air Pollutant Emission Factors – Volume II: Mobile Sources</u>, Table J-28). Idling for CO = 94.6 gm/hr winter conditions: 30° F, 13.0 psi RVP gasoline (<u>Emission Facts: Idling Vehicle Emissions)</u>.

[8] Gasoline (15 passenger) Vans that are 2 – 3 years old, High Altitude Light Duty Gasoline Truck for CO at 10 mph = 109.9 gm/mi., 25° F, 100% cold starts, calendar year = 2000 <u>Compilation of Air Pollutant Emission Factors – Volume II: Mobile Sources</u>, Table J-28). Idling for CO = 487.0 gm/hr hr winter conditions: 30° F, 13.0 psi RVP gasoline (<u>Emission Facts: Idling Vehicle Emissions)</u>. Appendix J High Altitude not available for 25.0 mph, but have Tables J-29 and J-30 High Altitude for 19.6 and 35.0 mph, respectively. Averaged the data: 53.38 gm/mi. + 35.63 gm/mi. = 89.01/2 = 44.51 gm/mi., 25° F, calendar year = 2000, 50% cold starts 50% stabilized 50% hot starts.

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